DSM 517

Advanced Applied Bayesian Inference for Data Science

Dynamic Pricing Models with Bayesian Neural Networks

Group Project

Instructor : **Prof. Suman Majumdar**

Prepared & presented by :

Group 01 : MSDSM Batch-03

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What is Dynamic Pricing?

Dynamic pricing is a **strategy** where **prices change** based on real-time factors such as **demand, customer behavior, and market trends.**

Real-life examples :

- Airlines booking
- Hotel booking
- Food delivery applications
- Ride-hailing services

Why is Dynamic Pricing important?

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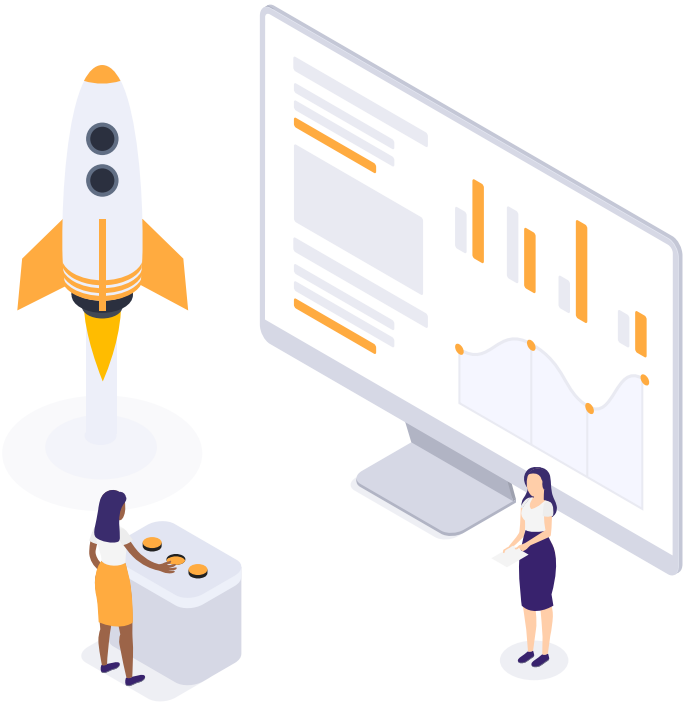
- Profit Maximisation
- Customer Retention
- Demand Prediction



Objective

This project aims to build a Bayesian Neural Network (BNN) to predict optimal quantity of the products sold while quantifying uncertainty, thereby maximizing revenue and enhancing customer satisfaction.

Data Set Used

The Dataset used in this project has been taken from

- UCI Machine Learning Repository - **Online Retail II**

https://archive.ics.uci.edu/dataset/502/online+retail+ii

iPython Notebook used :

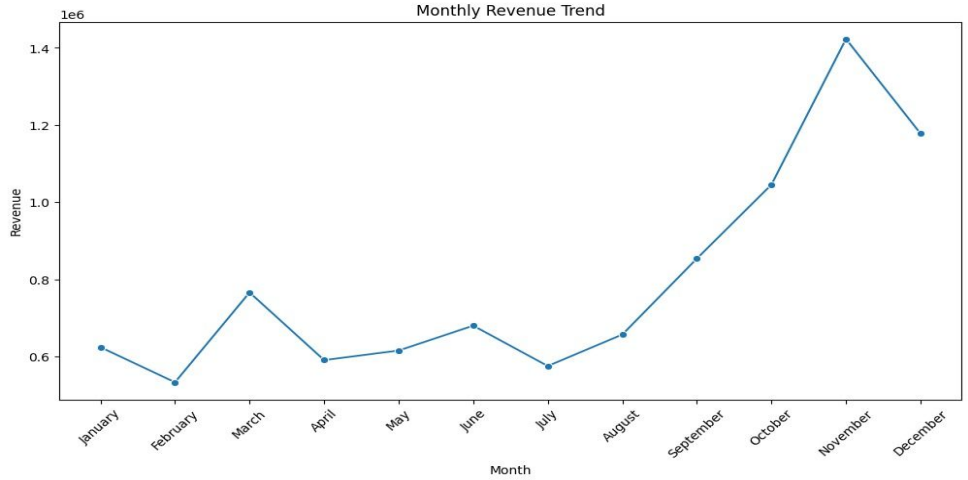
https://colab.research.google.com/drive/1Hn7uCw4ylQeJnmSADdBBUGvkhOgJrTf_?usp=sharing

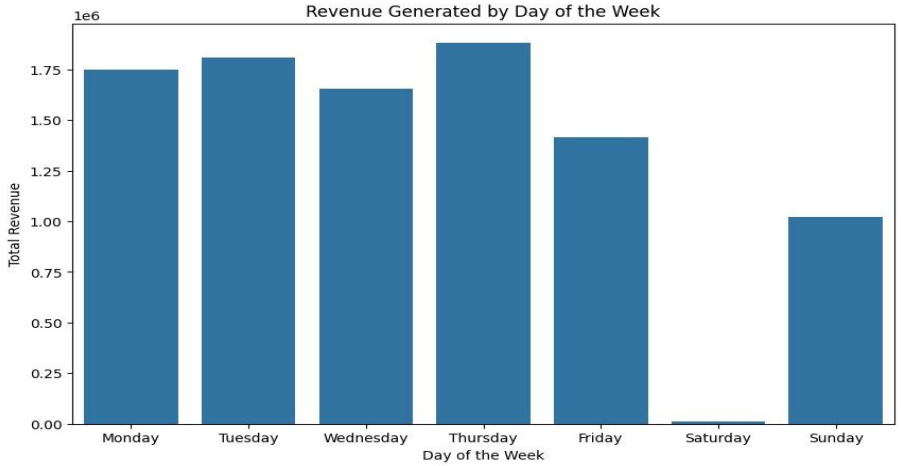
Data Set Attributes

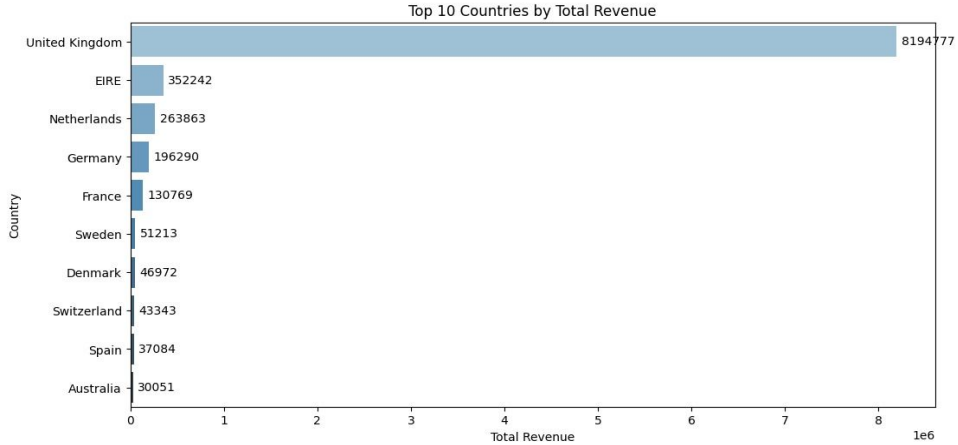
- **Invoice** (Transaction ID)
- **StockCode** (Product Code)
- **Description** (Product Name)
- **Quantity** (Number of items purchased)
- **InvoiceDate** (Timestamp of purchase)
- **Price** (Unit price of the product)
- **Customer ID** (Identifier for the customer)
- **Country** (Customer's country)

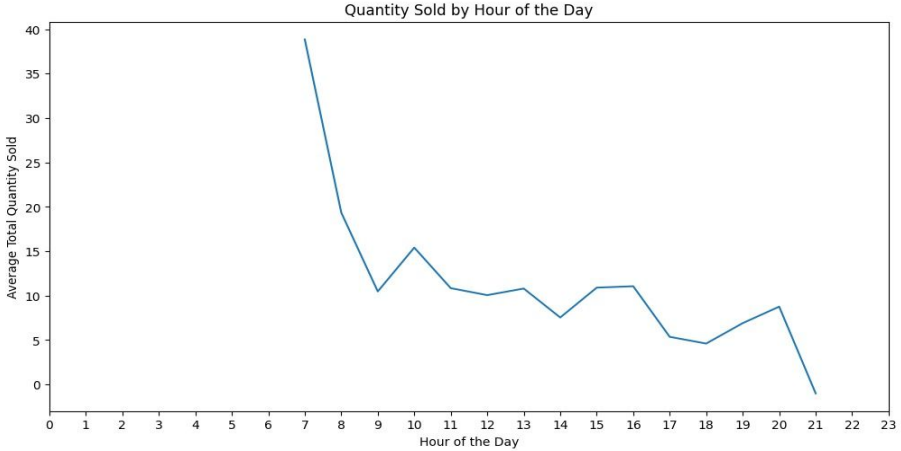
	InvoiceNo	StockCode	Description	Quantity	InvoiceDate	UnitPrice	CustomerID	Country
0	536365	85123A	WHITE HANGING HEART T-LIGHT HOLDER	6	2010-12-01 08:26:00	2.55	17850	United Kingdom
1	536365	71053	WHITE METAL LANTERN	6	2010-12-01 08:26:00	3.39	17850	United Kingdom
2	536365	84406B	CREAM CUPID HEARTS COAT HANGER	8	2010-12-01 08:26:00	2.75	17850	United Kingdom
3	536365	84029G	KNITTED UNION FLAG HOT WATER BOTTLE	6	2010-12-01 08:26:00	3.39	17850	United Kingdom
4	536365	84029E	RED WOOLLY HOTTIE WHITE HEART.	6	2010-12-01 08:26:00	3.39	17850	United Kingdom

Data Visualisation



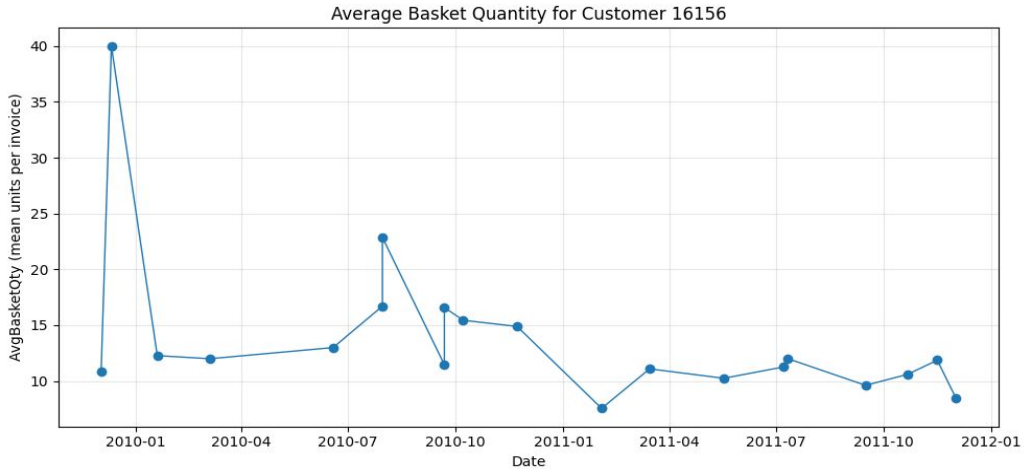


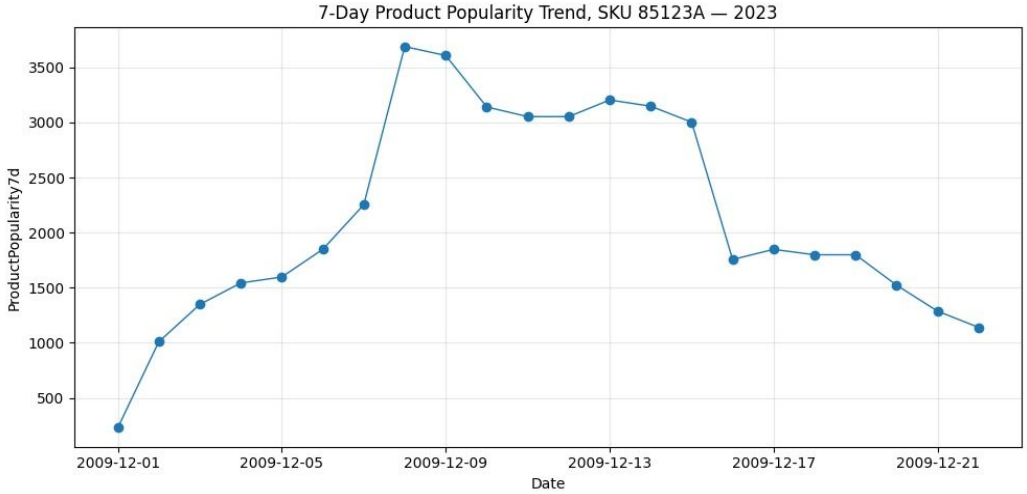




Features Engineering

- **Product Popularity 7-Day**
  (how trendy the item is this week)
- **Customer's Past Purchases**
  (loyalty indicator)
- **Average Basket Size**
  (big-cart shoppers behave differently)



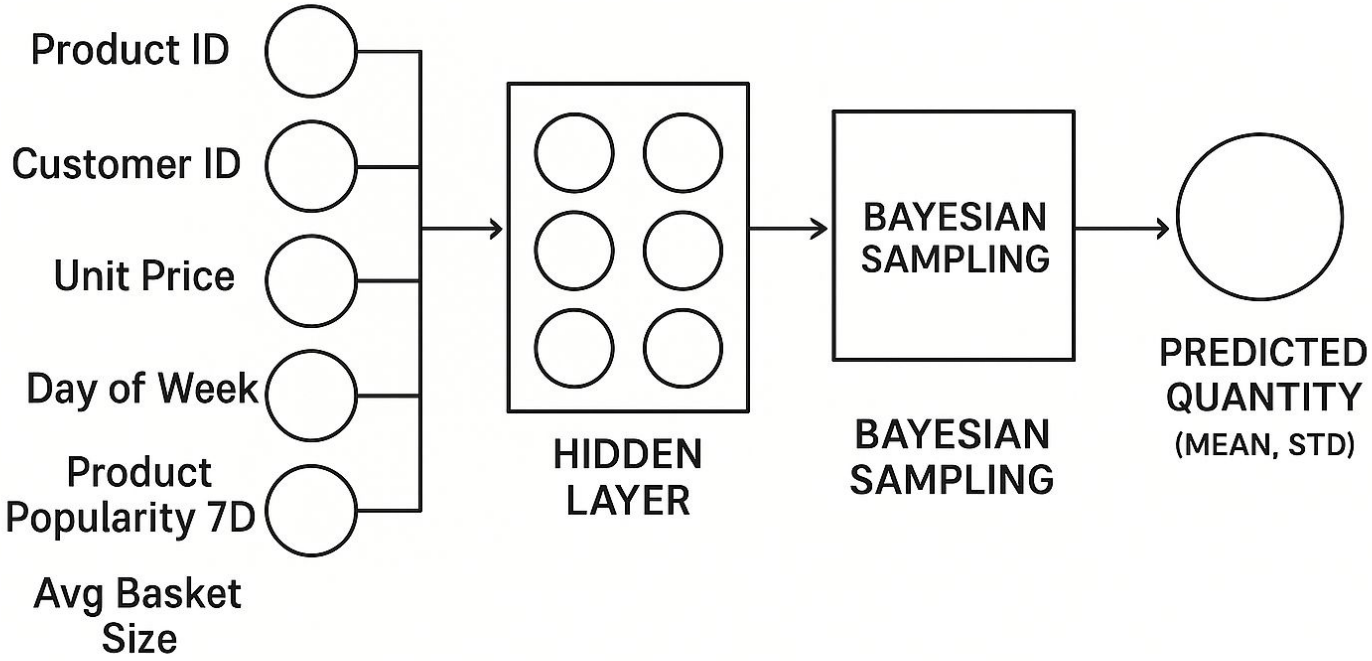


Methodology

- Clean & Pre-process the data
- EDA & Feature Engineering
- Model Setup: Bayesian Neural Network
- Loss Function & Training
- Dynamic Pricing Inference

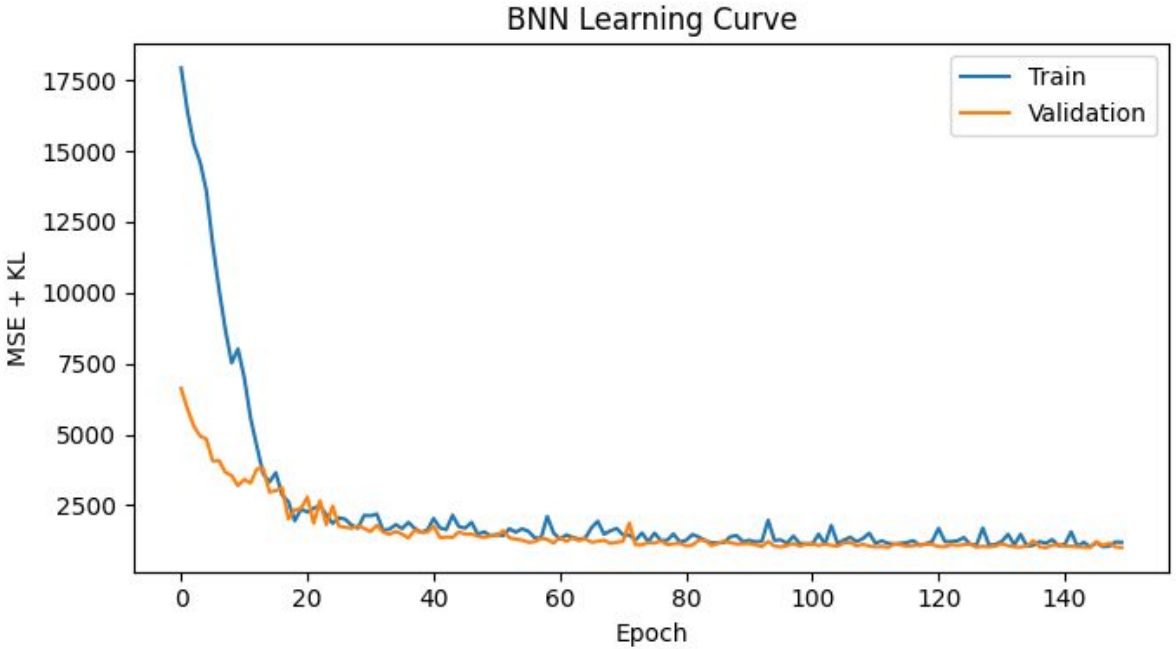
Why use BNN?
And not just ANNs?

BAYESIAN NEURAL NETWORK ARCHITECTURE FOR DYNAMIC PRICING



Why Predict Quantity? And not Price?

BNN Training

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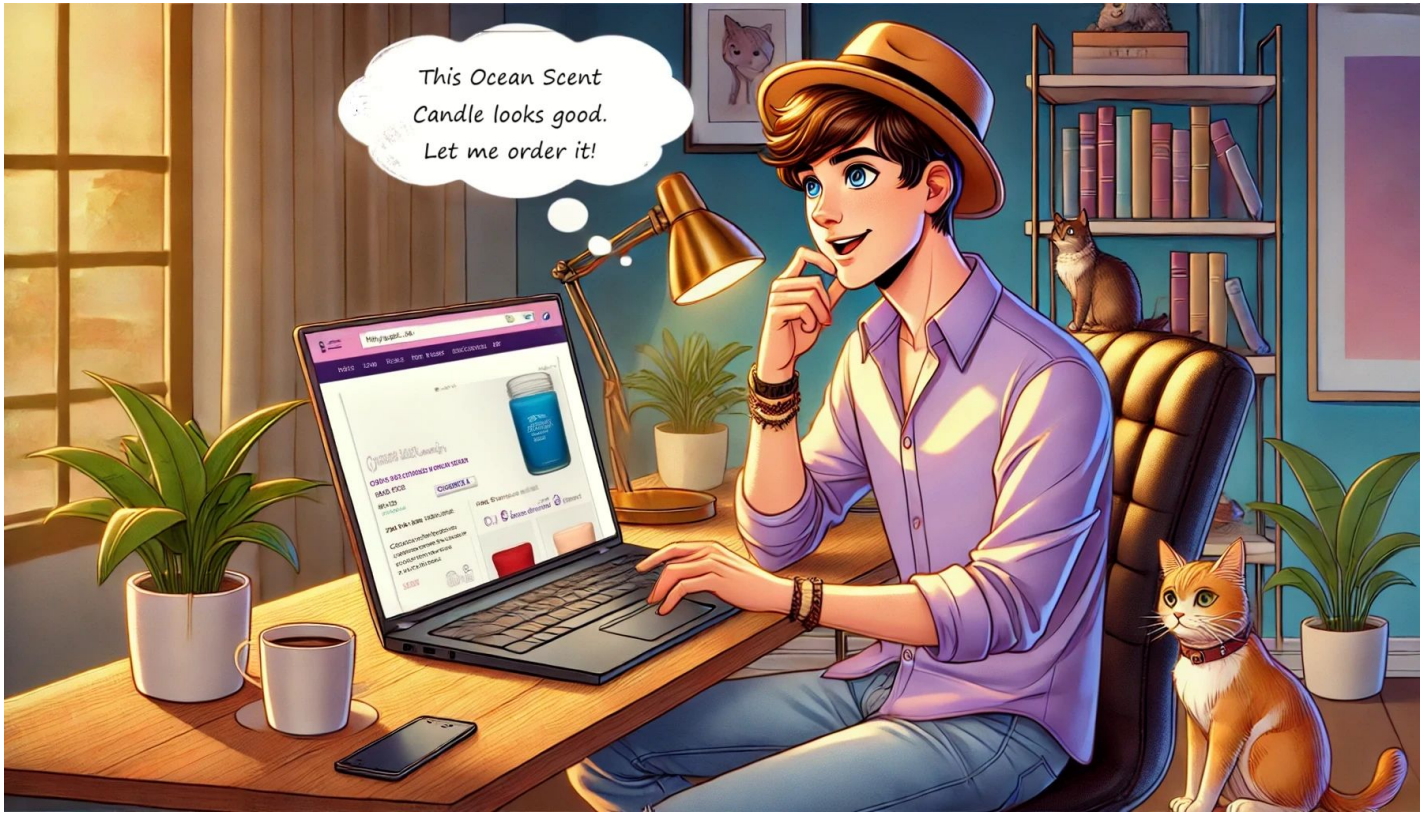
► TEST PERFORMANCE
   RMSE : 19.725
   MAE  : 5.231
   R²   : 0.853
```

Prediction Mechanism



Item: Ocean Scent Candles
Product ID: 2351
Original Price: $2.5
Date: 09/02/2025
Country: UK

Prediction Mechanism

Candidate Price	Predicted Qty (mean ± std)	Expected Revenue
2.00	9.8 ± 1.2	19.60
2.25	9.0 ± 1.3	20.25
2.50	8.0 ± 1.1	20.00
2.75	6.8 ± 1.0	18.70
3.00	5.5 ± 1.0	16.50

Prediction Mechanism

Candidate Price	Predicted Qty (mean ± std)	Expected Revenue
2.25	9.0 ± 1.3	20.25

Prediction Results

Candidate price	Quantity μ	Quantity σ	Expected Revenue
£6.80	5.3	0.63	£36.04
£7.65	4.92	0.63	£37.61
£8.50	4.53	0.63	£38.53
£9.35	***4.15***	***0.63***	***£38.80***
£10.20	3.77	0.64	£38.42
£11.05	3.38	0.64	£37.39
£11.90	3	0.64	£35.71

Suggested price: £9.35 (μ ≈ 4.15 ± 0.63)
Expected revenue ≈ £38.80

Limitations under the current scope of the project

- Cold-start for new customers or new products
- Not Robust to extreme value products
- Ignores cross-product cannibalisation

Alternate Methodology Tested

Original Approach

Train & Test set consisted of randomly distributed data points

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► TEST PERFORMANCE
   RMSE : 19.725
   MAE  : 5.231
   R²   : 0.853
```

Biased Approach

Train & Test consisted of data points for festive period only

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► TEST PERFORMANCE
   RMSE : 31.729
   MAE  : 8.561
   R²   : 0.655
```

THANK YOU!

iPython Notebook